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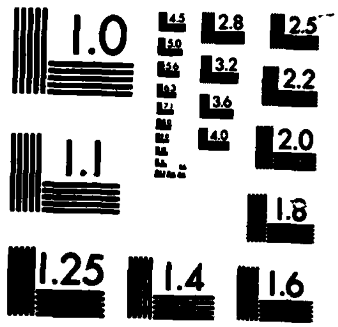

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The Structural and electrical changes caused by the implantation and annealing of donor and acceptor ions into $Hg_{1-x}Cd_xTe$ (x=0.2-0.3) were studied by a variety of ion-beam probing (RBS or PIXE combined with channeling) and electrical (C-V, Hall,photodiodes) techniques. Several annealing procedures (Furnace, Q switched Ruby laser and CW CO_2 laser) were tried. Best annealing was obtained when the implanted HgCdTe was heated for 0.4 seconds to 380°C by exposing it to a flash of photons delivered by a CW CO_2 laser. This novel mode of "Rapid Thermal Annealing" is shown to recover the crystal structure without causing changes in stoichiometry and to electrically

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activate both donor (B) and acceptor (P) implants. Mesa and planar p on n photodiodes, sensitive to IR radiation (3.5-5 μm), were obtained when this annealing procedure was employed to P implanted (200KeV, ~~2×10^{14} cm^{-2}~~) n-$Hg_{.71}Cd_{.29}Te$. Originator supplied keywords include:

2X 10 to the 14 Power/sq. cm

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LASER ANNEALING OF ION IMPLANTED HgCdTe

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Solid State Institute
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22 October 1984

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This report is intended only for internal management use.

Prepared for AFOSR

and

EUROPEAN OFFICE OF AEROSPACE RESEARCH AND DEVELOPMENT
London, England

Preface

The present report describes the work done, and the results obtained, by Prof. Kalish's group on the effects of ion-implantation and laser annealing of HgCdTe.

The support of the AFOSR for that project started on Oct. 1, 81, which is half a year later than originally planned. Some studies were thus already under way when the Air Force support started. Furthermore, during the period Oct. 1, 82 to Sept. 30, 83 Prof. Kalish has spent a sabbatical year at the IBM research laboratories and at the University of California at Santa Barbara working on Rapid Thermal Annealing of ion-implanted Si and InP.

These subjects are closely related to that of the present project. During this year some work on HgCdTe continued at the Technion, even though without any expenditure to the AFOSR grant.

The present report therefore summarizes work actually done in a period of about 3½ year, two of which have been supported by the AFOSR.

1. Introduction

Narrow band gap compound semiconductors are of great technological importance as infra-red detectors. Among those the semiconductor crystal $Hg_{1-x}Cd_xTe$ is of particular interest because of its band gap, which can be controlled by the stoichiometry of the crystal. For $X \approx 0.2$ the band gap of HgCdTe at 77K is about 0.1 eV which is the gap suitable for detection of infra-red photons of wavelengths around 10 μm. These are of special importance because of the transparency of the atmosphere to radiation of wavelengths between 8-14 μm. The electrical properties of HgCdTe are not only governed by impurities but also by the presence of defects; for example Hg vacancies probably act as acceptors while Te vacancies, or Hg interstitials, are believed to act as donors[1,2,3].

Ion implantation, which is by now a well established technique for doping Si, Ge and GaAs, could also turn out to be a very useful technique to introduce impurities into narrow band gap semiconductors[4], provided that good ways of annealing the radiation damage are found. The problems related to annealing of HgCdTe[5] are particularly severe. The high vapor pressure of Hg and the thermal instability of HgCdTe complicate all thermal treatments of this material. Studies of ion implanted $Hg_{1-x}Cd_xTe$ (x=0.2-0.3) have shown[6] that n-type conductivity was always obtained regardless of the implant atomic number (whether H,Ar,B,Al,P or In) and regardless of the initial substrate conductivity, indicating that it must be the radiation damage which is responsible for the conductivity rather than the dopant. Even though it was possible to obtain photosensitive devices by creating ion induced damage in p-type HgCdTe substrates, the advantages of the excellent control which

implantation doping can normally offer-and thus the possibilities of incorporating other devices on the same chip are clearly lost. It is therefore of great importance to find implantation and annealing conditions in which the implant will be the donor, or acceptor, and not the damage related to its implantation.

To overcome the problems of dopant diffusion or changes in stoichiometry associated with high temperature furnace annealing, pulsed and CW laser annealing as well as a variaty of Rapid Thermal Annealing (RTA) techniques have recently been applied to implanted Si, Ge and to some compound semiconductors (GaAs, InP, $Pb_{1-x}Sn_xTe$ and $Hg_{1-x}Cd_xTe$) crystals[7]. While this novel technology has already yielded very satisfactory results for Si, the results on compound semiconductors are still meager. The best results reported for compound semiconductors are for GaAs where promising results were obtained by laser annealing[8]. The advantages of succesful short time annealing of implanted HgCdTe and other chemically "delicate" compound materials can be very substantial since the heating of the crystal can be limited to short times hence minimizing mass redistribution and changes in stoichiometry which cause undesired changes of the electrical properties.

Since n-type conductivities can easily be achieved in MCT by just damaging HgCdTe we have concentrated in the present study on the annealing and electrical activation of <u>acceptors</u> in HgCdTe. If, as a result of proper annealing of acceptor implanted n-HgCdTe, the damage associated n^+ conductivity changes to p type than this can be taken as proof that real activation has been achieved; in particular if this does not happen when donor or neutral ions are implanted and annealed under identical conditions. We have indeed succeeded to show that for the case of P, B and Ar implantations

into n-$Hg_{.79}Cd_{.21}Te$ hole and electron conductivities respectively are obtained.

The present research concentrated on finding annealing procedures which will electrically activate the implants, anneal the radiation damage yet leave the crystal composition unchanged. We have succeeded to achieve those goals by developing a Rapid Thermal Annealing (RTA) technique which is an extension of "laser annealing" in the solid phase recrystallization regime. In this technique the samples are heated for fractions of seconds to $\approx 300^{\circ}C$ by means of a single shot of photons delivered by a CW CO_2 laser.

Below we describe the technical aspects of the implantations and the annealing technique; we show results of studies in which the recovery of the crystal and its near - surface structure and composition are investigated by various ion beam probing techniques (Rutherford backscattering (RBS), Particle induced x ray emission (PIXE), and Auger Spectroscopy) and finally show results which prove that the implanted dopants have indeed been electrically activated and photosensitive p on n diodes have been obtained.

2. Technical

2a. Samples

The samples used were $Hg_{1-x}Cd_xTe$ with x ranging from 0.21 to X=0.29. Both n and p type crystals were studied ; The samples were repeatedly used by removing the surface layers by mechanical polishing (down to 0.3 μm) followed by chemical etching in 10% Bromine Methanol.

Implantations were carried out into randomly oriented crystals held at either 77° or $300^{\circ}K$. A variety of ions, delivered by the Technion's Danfysik - HVEE 350kev accelerator, were implanted. The ions studied were

B, Al, P, Ar, In, Xe and Hg which were implanted with energies between 100 and 300keV to doses varying from 10^{13} cm^{-2} to $5x10^{14} cm^{-2}$.

Prior to annealing the damaging effects caused by the implantation were measured both by ion beam probing methods as well as electrically (see below). A 1.2 μm thick ZnS Cap was evaporated on to some implanted regions prior to annealing. This served as a protective cap, as an antireflection coating for the 10.6 μm CO_2 laser radiation and as a convinient visual indication to help determine the desirable annealing conditions (see below). The cap was chemically removed after annealing.

2b. <u>Annealing</u>

(i) <u>Furnace</u>:

Some control samples kept in a closed ampule under over pressure of Hg were annealed in a furnace at 250°C for 30 minutes.

(ii) <u>Pulsed Q-switched Ruby laser</u>: [9,10]

Annealing through the liquid phase recrystallization was attempted by exposing the samples to single or several short pulses of photons with λ =0.69 μm delivered by a Q Switched Ruby laser. Pulse durations of $\approx$ 50 nsecs with energy densities ranging from 0.1 to 0.25 J/cm^2 were employed. The absorption of MCT to this radiation is high ($\approx 10^4$ cm^{-1}) so that all the laser energy is practically absorbed in a layer of thickness comparable to that of the implanted layer. When melting was reached the cap has completely vanished and, as described below, loss of Hg from the near surface was evident.

(iii) CW CO_2 laser [9,10]

Photons delivered by a CO_2 laser (λ=10.6 μm) have an energy of $\approx$ 0.1eV which is below the band gap of $Hg_{1-x}Cd_xTe$ for both x=0.21 and 0.29. The absorption coefficient is therefore very low, of the order of 1-10 cm^{-1}. Hence the interaction with the radiation is predominantly through free carriers or defects.

In the present work the laser beam has been defocused to a diameter of about 2 cm so that the complete sample (~ 1 cm in diameter) could be irradiated in one shot. (Some preliminary experiments were done with a smaller beam which was scanned, by computer control, over the sample). Power levels of 50-300 W/cm^2 were used, and pulse lengths (also controled by computer) were of the order of 0.1-0.5 seconds.

(iv) Sample temperature determination

It is very important to know the Temperature (T)-time(t) profile that the sample experiences during the annealing. However, the problem of accurately determining the momentary temperature of samples exposed to Rapid thermal annealing is hard and has not yet been solved satisfactorily even for Si. We have made attempts to measure the MCT temperatures while exposed to the CO_2 laser light by two different approaches: (i) A thermocouple has been glued into a hole etched in a dummy MCT sample of dimensions similar to those of the sample to be annealed. The T-t curves, as read on this sample, were calibrated against the laser power, and were assumed to be the same for the "real" sample. (See figure 1 for a typical T-t curve). The problem with this technique is the short "lifetime" of the thermocouple arrangement which tends to break when exposed to repeated thermal cycles. (ii) A special contact-less thermal censor based on the pyroelectric effect has been purchased (from "Galai") and modified to accomodate our

special requirements of temperatures and response times. This instrument has been calibrated against samples with thermocouples attached to them which were heated in a furnace. The instrument is now ready to be used to probe the T-t of samples exposed to CO_2 laser light. The scattered 10.6 μm radiation should not interfere with the measurement since it is selectively absorbed and is beyond the sensitivity region of the detector.

2c. Ion beam probing[11)]

Ion beam probing techniques are non-destructive, are fairly easy to apply, (require no contacts, masks etc.) and can yield information on the crystallinity and composition of near surface regions. They were therefore employed to initially search for the optimal annealing conditions and to study the nature of the defects in implanted HgCdTe. Use was make of the channeling effect in connection with the RBS and PIXE techniqes. Proton and He beams delivered by the implanter or by a 1MV Van de Graaff accelerator were used. The findings of these studies, some of which are of general interest and applicable also to the probing of other compound III-V or II-VI semiconductors, have been described in detail in the enclosed publications.

2d. Electrical measurements

A variety of techniques were employed to determine the electrical properties of the un-implanted, implanted and annealed samples. These include:

(i) Hall measurements

The measurements were carried out in two stages: First Van der Pauw measurements were performed to obtain a rough idea of the conductivity and carried type, and, at a later stage, careful measurements as function of

temperature were done on special Hall structures. For the case of n^+ on n layers, such as resulting when n-HgCdTe is damaged by implantation, the Petritz two layer analysis was employed[12]. It enables to separate the conductivity and mobility of carriers in the top (n^+) layer from that of the substrate material. When n^+ on p layers were measured a junction is formed as a result of the implantation, so that the properties of the isolated top layer can be directly determined. All Van der Pauw measurements were carried out at 77°K.

The temperature dependent Hall measurements were performed at a later stage. For these special Hall structures on thin 50 μm thick samples glued auto Saphire were prepared. The same sample was measured before implantation, after P, B or Ar implantation, and after CW CO_2 laser annealing. This enabled accurate determination of the properties of the carriers . The measurements were carried out on p type material (X=0.29) implanted with P (200KeV, 2×10^{14} cm^{-2}) or B (150KeV, 2×10^{14}cm^{-2}) and on n-type material (x=0.29, 0.21) implanted with 200KeV B to a dose of 2×10^{14} cm^{-2}. The temperature range was 20-300°K. For these measurements, only preliminary results are available at present.

(ii) C-V measurements

Metal-Insulator-Semiconductor (MIS) structures were manifactured on the sample to enable c-v measurements. The insulator used was 3000Å thick ZnS on which 250x250 μm^2 In dots were evaporated. Various regions (unimplanted, B or P implanted and Ar implanted) were created on the same wafer and all were measured prior to and following annealing. The measurements were carried out at 77°K at 1MHz with a 15 mV signal.

(iii) p on n diodes

P on n photosensitive diodes were obtained by applying the CW CO_2 laser annealing procedure to P implanted n-$Hg_{.71}Cd_{.29}Te$. The substrate material had a carrier concentration of $2.7\times10^{16}cm^{-3}$, a Hall mobility of $2\times10^4cm^{-2}V^{-1}sec^{-1}$ and a conductivity of $92\,\Omega^{-1}cm^{-1}$. Half of it was implanted with 200KeV P to a dose of $2\times10^{14}cm^{-2}$. After ZnS encapsulation (1.2 μm) the samples have been subjected to a 0.4 sec irradiation from the defocused CO_2 laser at a power of $200W/cm^2$. This has caused the sample to reach a temperature of $\sim 380^oC$ for 0.1 sec (see fig. 1) . However, in light of the difficulties involved in the determination of the transient temperature discussed above, these values are uncertain.

Mesa as well as planar structures were produced . A thin native sulfide passivation layer and a ZnS antireflection coating were deposited on the diodes.

3. Results

3a. Sturctural

The results of the ion beam studies regarding the nature of the implantation induced defects in HgCdTe and of the quality of the crystals and their composition following the various annealing techniques employed has been documented in detail in the open literature (see enclosed papers ref. 10,11).

Here we therefore only summarize the main findings of these studies:

(i) Damage in as - implanted material

- The damage caused by room temperature implantation of a veriety of ions (Al, P, Ar, In, Hg) reaches saturation when $2\text{-}4\times10^{24}$ eV/cm^3 goes into nuclear collisions;

- The damage profile for light ion implantation (P, Ar) is more shallow than the implant range while for heavy implants (In, Hg) it extends substantially deeper than the range.
- the damage consists of extended defects, probably stacking faults.

(ii) Damage annealing

- Hg seems to block the channels(after Hg implantations) even following furnace annealing.
- Pulsed Ruby laser annealing is very hard to control, and most times leads to severe loss of Hg.
- Good annealing as far as channeling and near surface composition are concerned is obtained when the implanted surface is irradiated with photons from a CW CO_2 laser for 0.3s at a power of 250 W/cm^2. Under such conditions the crystallinity is restored and no changes in stoichiometry are evident.

3b. Electrical

(i) Van der Pauw measurements

The results of conductivity measurements bythe Van der Pauw technique have already been published (see enclosed)[13)]; The summary of the results is as follows:

- The defects related to the implantation cause the near-surface layer to be n^+, regardless of substrate material (n or p-type or various x values of $Hg_{1-x}Cd_xTe$) and of implanted ion.
- The density of donors created by the implantation reaches a saturation value which is $n_s \simeq 8\times10^{13} cm^{-2}$ for n-$Hg_{1-x}Cd_xTe$ (X=0.215) and $n_s \simeq 3\times10^{14} cm^{-2}$ for p-$Hg_{1-x}Cd_xTe$ (x=0.29).
- The saturation is reached for an implantation dose of 8×10^{12} cm^{-2} when 100KeV B ions are implanted, and is even lower for heavier ions. This saturation value is x100 lower than the dose needed to reach saturation in damage as observed by RBS (see fig 1 and Table 1 in ref 13).

- The carrier density exceeds the implant density for below-saturation implantations by several orders of magnitude.
- The mobilities in n or p-type implanted layers are $\mu_n(n) \approx 10^4 cm^2V^{-1}sec^{-1}$ and $\mu_n(p) \approx 10^3 cm^2V^{-1}sec^{-1}$ respectively.

The above observations all lead to the conclusion that the donors in as-implanted HgCdTe are related to implantation induced defects. Unfortunately it is impossible at the present stage to tell what defect is responsible for it.

(ii) Hall measurements

Most temperature dependent Hall measurements were carried out on p-$Hg_{.72}Cd_{.28}Te$ implanted with 200KeV P or 150KeV B ions to a dose of $2x10^{14}cm^{-2}$. Preliminary results are shown in figure 2 in which the Hall coefficient (R_H),the Hall mobility (μ_H),and the conductivity (σ) are displayed as function of Temperature (or 1/T). The +, o and * simbols correspond to results obtained on virgin, as implanted and CW CO_2 laser annealed samples respectively. The plotted values of μ_H and σ were calculated under the assumption that the samples are of uniform thickness,which is not true. After implantation the samples turned n^+ on p and after annealing and implant activation they became p^+ on p or n on p depending on implanted ion (P or B). The plots, therefore, only illustrate the type of conductivity. The results of accurate calculations carried out so far only for 77^oK are given in table 1. . They clearly show that dopant activation is obtained by proper annealing.

(iii) C-V measurements

The results of these measurements, ment to varify that dopant activation is obtained following CW CO_2 laser annealing, have been

published (see enclose, ref. 13). The fact that an inversion layer is formed and that a narrow band gap material, as used here, can not be driven into deep depletion prevented us from obtaining results on the depth distribution of the effective carriers. However, by comparing the shape of the measured C-V curve for the B implantation to theoretical curves calculated for various values of N_A-N_D we estimate that an effective doping level of $5x10^{17} cm^{-3}$ was obtained following annealing; in agreement with the more direct results obtained from the Van der Pauw measurements.

(iv) p on n diodes

As a final proof and most crucial test for the activation of implants in HgCdTe we have demonstrated that photosensitive p on n diodes can be produced by the CW CO_2 laser annealing technique.

Mesa as well as planar structures were produced. A thin native sulfide passivation layer and a ZnS antireflection coating were deposited on the diodes. The I-V characteristic of a P implanted mesa diode measured at $77^{o}K$ is shown in figure 3. . The photocurrent is due to the $300^{o}K$ background measured under 180^{o} field-of-view. The spectral photoresponse of the diode is shown in figure 4. . It has a peak at 4.5 μm and a 50% cutoff at 5.2 μm in accord with the initial composition of the crystal.

We attribute the p-type conductivity responsible for the observed diode behavior to the electrical activation of the P implants. Even though Hg vacancies are known to be acceptors in HgCdTe and hence may lead to p-type conductivity, we believe that the presently employed rapid thermal annealing of encapsulated HgCdTe inhibits the formation of such conductivities. As we have shown, in our previous studies described

above, the annealing technique used in the present experiment can electrically activate both donor (B) and acceptor (P) implants in HgCdTe. In the work described in ref. 13 n-$Hg_{.71}Cd_{.29}Te$ was implanted with B, P and Ar ions (expected to be donors, acceptors and neutrals in HgCdTe). Following the implantations, the well known damage-related n^+ layers were formed. However, after annealing under conditions similar to these employed in the present experiment, the P implanted samples turned p-type , the B implanted ones stayed n-type with carrier concentrations proportional to the implant dose while the Ar implanted sample stayed n-type with a reduced carrier concentration. B implanted Hall structures which were annealed simultaneously with the present diodes have verified this: The Hall measurements having shown improved n-type conductivities while the identically annealed P implanted n-HgCdTe have exhibited the diode characteristics described above. Had Hg loss been the cause for the p-type conductivity in the diodes, similar losses should have occurred in the B implanted Hall samples which should then have shown p rather that n-type conductivities. Furthermore, no planar diodes would have been observed if the n-HgCdTe which surrounds the implanted region had turned p-type because of Hg loss. The possibility that the implanted regions heat up more than the non-implanted ones due to higher absorption of the 10.6 μm radiation cannot be ruled out. However, as shown, this does not seem to lead to Hg loss when short time annealing of encapsulated samples are used and the laser power is not too high. While photosensitive p on n planar diodes were formed in P implanted regions, control diode structures on the same wafer which have not been implanted but have been subjected to the same laser pulse did not exhibit any rectifying behavior. The visual appearance of the ZnS cap which starts to crack at the right laser power was identical in the implanted and non-implanted regions indicating that uniform temperatures were reached over the whole 1cm wafer as a result of the laser pulse.

Summary

The present study, which was affectively active for over 3 years, two of which supported by the AFOSR, has led to a better understanding of implantation induced damage in HgCdTe and its annealing. While the first stages of the study have concentrated on structural studies, the later ones were extended to electrical measurements with the final result of the production of photosensitive diodes. The yield, however, is still low so that despite the fact that diodes of two different kinds (mesa as well as planar structures),were realized in several independent runs much more work is needed to turn the procedure developed in the present work into a process relayable enough for the production of ion implanted devices in HgCdTe.

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Figure Captions

Fig. 1: Typical temperature vs time curve measured by a thermocouple bonded to an oxidized Si wafer exposed to light from a cw CO_2 laser (200 W, 0.4 sec).

Fig. 2: Hall constant vs. temperature for p type HgCdTe $x=0.29$ before implantation +, after 200 keV 2×10^{14} cm^{-2} phosphorus implantation O and after CW CO_2 laser annealing*.

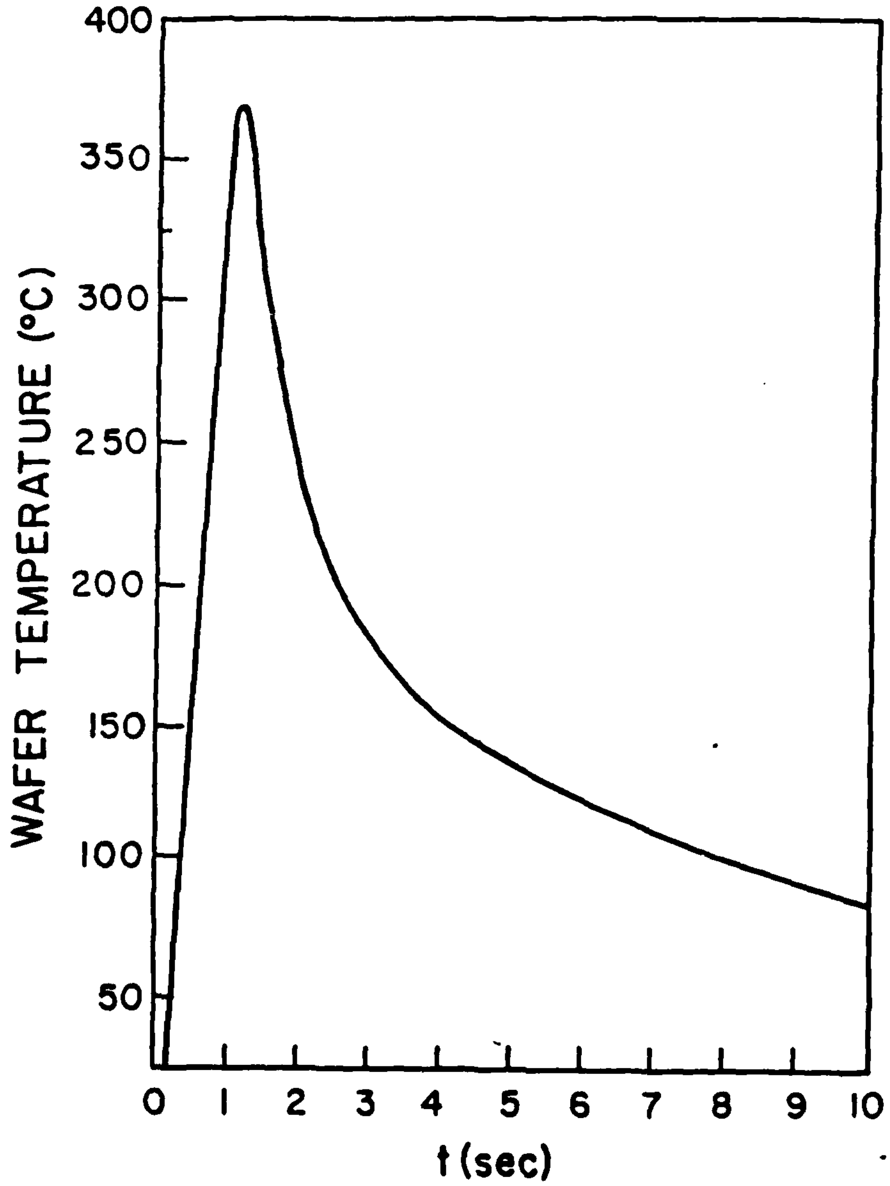
Fig. 3: I-V characterisitc of p^+ on n-$Hg_{.71}Cd_{.29}Te$ photodiode measured at 77K under 180° field of view background.

Fig. 4: Relative photoresponse of p^+ on n $Hg_{.71}Cd_{.29}Te$ photodiode measured at 80K.

Table 1: The measured and calculated electrical parameter of implanted and annealed at 77°K in HgCdTe n_s and p_s are the calculated sheet majority carrier concentration per unit surface and σ_s is the calculated sheet conductance.

Measured Parameters / Sample	type	Hall Constante $R_H(cm^2 \cdot Cb^{-1})$	Hall Mobility $\mu(cm^2 \cdot v^{-1} \cdot s^{-1})$	Conductivuty
A x=0.28 unimplanted	p	$R_H=4.29 \cdot 10^2$ $n(cm^{-3})=2.7 \cdot 10^{16}$	$\mu=1.03 \cdot 10^3$	$\sigma(\Omega^{-1} \cdot cm^{-1})=$ 2.4
A Boron implantation 150keV, $2 \cdot 10^{14} cm^{-2}$	n	$R_H=3.08 \cdot 10^2$ $n_s(cm^{-2})=$ $=1.12 \cdot 10^{14}$	$\mu_s=4.48 \cdot 10^3$	$\sigma_s(\Omega^{-1})=$ $=8.12 \cdot 10^{-2}$
A Boron Implantation Laser annealing	n	$R_H=2.1 \cdot 10^2$ $n_s(cm^{-2})=$ $=1.6 \cdot 10^{14}$	$\mu_s=3.9 \cdot 10^3$	$\sigma_s(\Omega^{-1})=$ $=1.04 \cdot 10^{-1}$
B x=0.28 unimplanted	p	$R_H=3.74 \cdot 10^2$ $p(cm^{-3})=$ $1.67 \cdot 10^{16}$	$\mu=5.29 \cdot 10^2$	$\sigma(\Omega^{-1} \cdot cm^{-1})=$ $=1.42$
B Phosphorus Impl. 200keV, $2 \cdot 10^{14} cm^{-2}$	n	$R_H=4.43 \cdot 10^2$ $n_s(cm^{-2})=$ $=6.3 \cdot 10^{13}$	$\mu_s=4.06 \cdot 10^3$	$\sigma_s(\Omega^{-1})=$ $=4.1 \cdot 10^{-2}$
B Phosphourus Impl.+ Laser annealing	p	$R_H=1.39 \cdot 10^2$ $p_s(cm^{-2})=$ $=9.2 \cdot 10^{13}$	$\mu_s=2.07 \cdot 10^2$	$\sigma_s(\Omega^{-1})=$ $=9.2 \cdot 10^{-3}$

Fig. 1.


400
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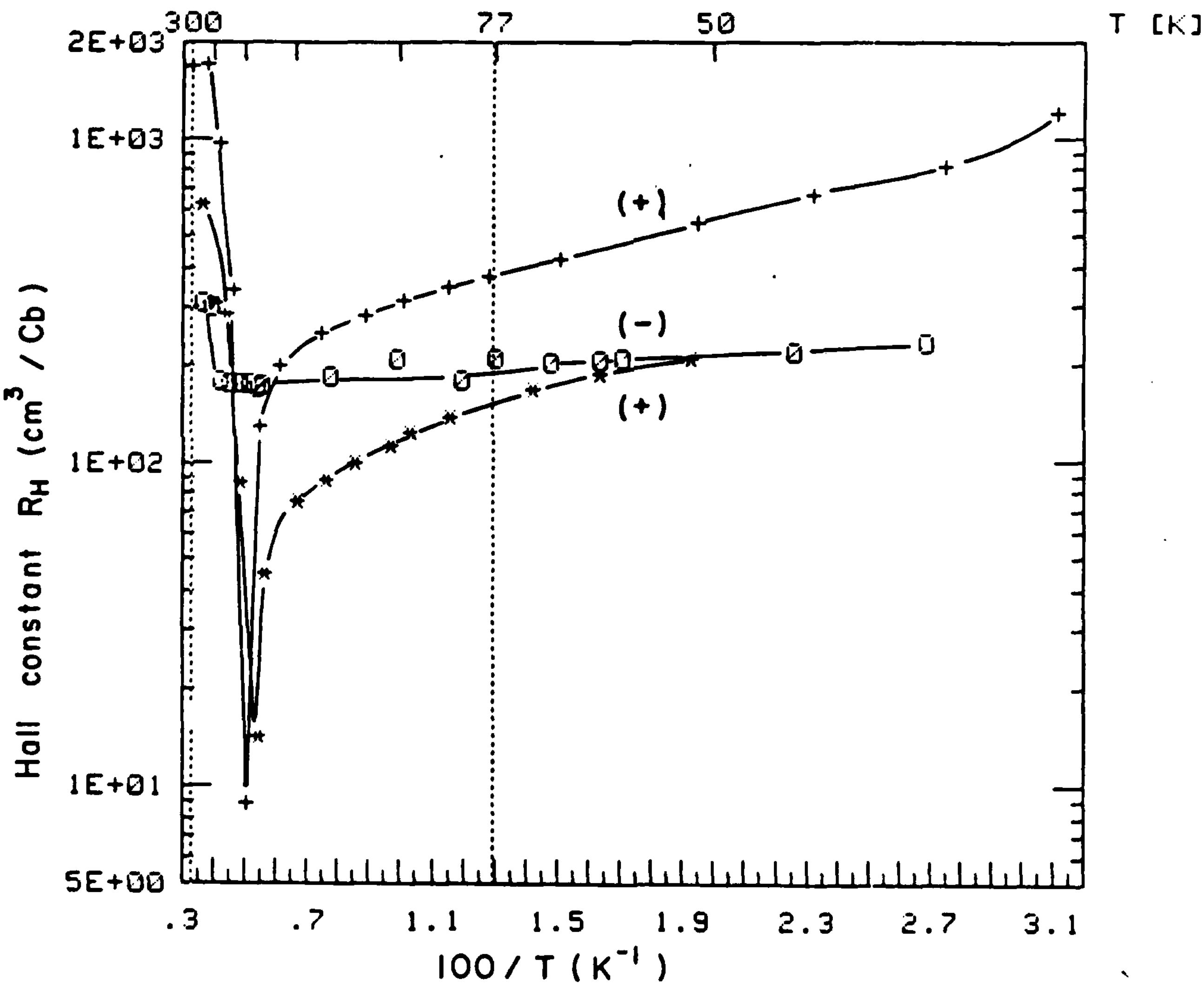
t (sec)

Fig. 2.



300
77
50
T [K]
2E+03
1E+03
1E+02
1E+01
5E+00
Hall constant R_H (cm^3 / Cb)
(+)
(-)
(+)
.3
.7
1.1
1.5
1.9
2.3
2.7
3.1
100 / T (K^{-1})

Fig. 3.

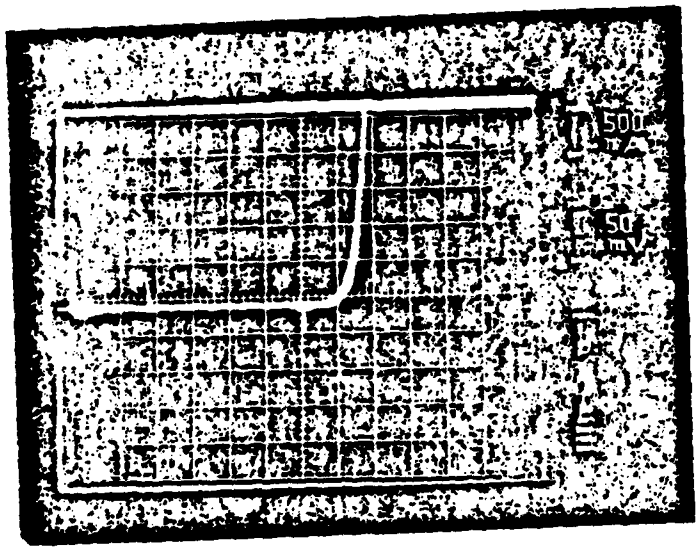
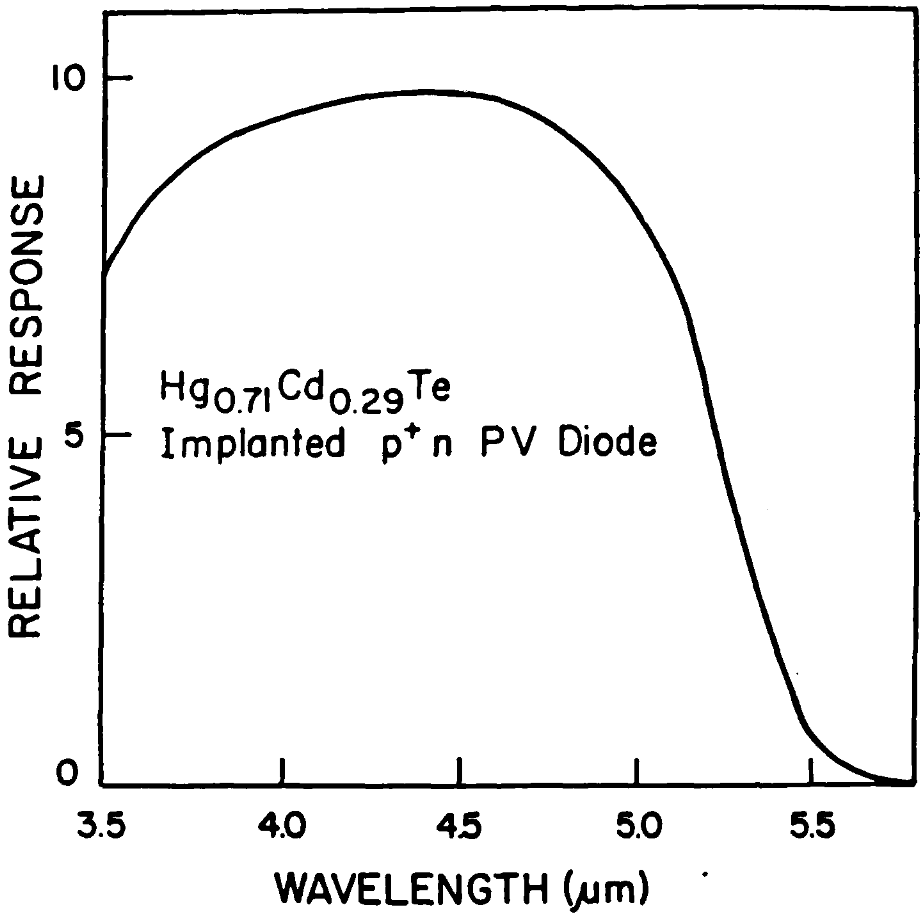


Fig. 4.


10
5
0
RELATIVE RESPONSE
Hg0.71Cd0.29Te
Implanted p+n PV Diode
3.5
4.0
4.5
5.0
5.5
WAVELENGTH (µm)

The above findings were summarized in several publications and reports (not all done during the period of US AFOSR Support) which are:

(1) "CW CO_2 laser annealing of ion-implanted $Hg_{1-x}Cd_xTe$" by G. Bahir and R. Kalish, Appl. Phys. Letters 39(9), 730 (1981).

(2) "The structure of ion implanted and annealed $Hg_{1-x}Cd_xTe$" by G. Bahir and R. Kalish, J. of Appl. Phys. 54, 3129 (1983).

(3) "The structure of implantation induced damage in HgCdTe" by G. Bahir and R. Kalish. Abstract and poster presentation at the International Conference on "Ion Beam Modification of Materials" Grenoble, France, Sept. 1982.

(4) "Electrical properties of donor and acceptor implanted HgCdTe following CW CO_2 laser annealing", G. Bahir, R. Kalish and Y. Nemirovski Appl. Phys. Letters 41, 1057 (1982).

(5) "PIXE analysis of compound materials "R. Kalish and G. Bahir Nucl. Insts. of Methods 218, 415 (1983).

(6) "Ion implantation and annealing of HgCdTe", G. Bahir to be published in the J. of Vacuum Science and Technology (San Diego HgCdTe workshop).

The findings of the present work were reported in Israel in two seminars held at the Technion, in an oral presentation delivered at the Annual Meeting of the Israel Physical Society (April 1981),were discussed at the Annual Meeting of the Materials Research Society (Boston, November 1981) were presented on a poster at the "Ion Beam Modification of Materials" Conference in Grenoble (Sept. 1982) and were presented in an invited talk at the San Diego US workshop on the Physics and Chemistry of HgCdTe(April 1984).

No patents have been submitted on the subject of the present research.

The personnel involved in the research area:

Half-time: Prof. R. Kalish - Principal investigator

Full time: Dr. G. Bahir

Half-time: Mr. A. Lavi - Technician

Half-time: Mr. V. Richter - Engineer

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